

Induced Deficiency Symptoms of Nitrogen, Phosphorus, Potassium, Magnesium and Iron in *Axonopus compressus* Cultured in Sand

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Abstract

The deficiency symptoms of N, P, K, Mg and Fe were successfully induced in *Axonopus compressus* cultured in sand. Visual deficiency symptoms are presented and described in detail. Dry matter of above- and below-ground parts was determined. Data of elemental analysis of above-ground parts of normal and deficient plants are tabulated for comparison.

Introduction

Axonopus compressus commonly known as carpetgrass or locally as cowgrass, is a native of the West Indies. Its pantropical distribution has been encouraged mainly by its quality as a pasture grass (Gilliland, 1953). It grows on non-fertile, wet, acid, sandy and sandy loam soils, where moisture is near to the surface most of the year and on soil too poor for other pasture plants.

In Singapore, *Axonopus compressus* (Swartz) Beauv. has become the major turfgrass groundcover used for sports fields, home lawns, parks, road verges and other open spaces, in recognition of its hardy nature — high resistance to wear and tear, rapid rate of establishment notwithstanding poor soil conditions, competitive superiority over weeds and inherent resistance to diseases and insect pests. However, *Axonopus compressus* is rarely found as a pure stand unless under stringent control as on home lawns. Often it is mixed with minor populations of interspersed *Digitaria didactyla*, *Cynodon dactylon* and *Zoysia matrella* (Anonymous, 1977) whose coexistence is tolerated.

Recently, patches of chlorotic *Axonopus compressus* were discovered in various horticultural locations in Singapore, especially where the soil pH values were 7.0 and above. Vengris (1973) reported that *Axonopus compressus* is very prone to iron deficiency, having the disposition to become chlorotic at pH 7.0 and above and that the ideal pH range for *Axonopus compressus* is 5-5.5. Whereas the nutritional requirements of temperate grasses have been studied in some detail (Beard, 1973 & 1979; Madison, 1971 and Vengris, 1973), little is known about the nutrition of *Axonopus compressus*. The following nutrient-omission trial was designed to study the deficiency symptoms of essential elements in *Axonopus compressus* and to specifically relate the chlorotic symptom encountered in the field to iron deficiency.

Materials and Methods

Clusters of *Axonopus compressus* with intact root systems were collected from the grounds of the Singapore Botanic Gardens and washed free of all soil contaminants. After

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a final rinse with deionized water, they were transplanted into plastic pots approximately 20 cm in diameter, filled with washed sea sand. The sand had been thoroughly cleaned with water to remove fine clay and silt particles, and soluble salts, then leached with N HCl to remove exchangeable cations if any, and finally rinsed with deionized water until acid-free. The top of each pot was lined with a layer of washed granite chips to prevent the possible loss of sand due to the splashing by the rain and to reduce evaporation. The planted pots were left to establish under shade for a few days before being exposed to full sun on beaches in open ground.

Nutrient formulations were adapted with minor adjustments from Asher (1973) and are tabulated (Appendixes 1 & 2). Such formulations have been successfully employed by Chai (1978) in inducing mineral deficiency symptoms in Choy Sam (*Brassica chinensis*) by solution culture. Salinity of each nutrient feed was checked and the pH corrected to 5-5.5 before application.

Each treatment as well as the control are replicated 6 times. The controls, given a full complement of essential elements, were kept for comparison. In addition, 6 pots were incorporated for a study of the perseverance of *Axonopus compressus*. The latter was raised solely with deionized water.

The pots were fertilized on alternate days at the rate of 150 ml per pot and supplemented with deionized water on other days.

Deficiency symptoms were registered photographically as they appeared and where possible, the sequential development of symptoms was also photographed. When the trial was 3-months old, a representative pot from each treatment showing deficiency symptoms was harvested and the root system compared with that of the control. The remaining pots were also harvested and separated into roots and tops. Three lots of these were washed, dried at 80°C, pulverized and used for elemental analyses. The other three lots were dried at 105° C for dry-matter determination.

Results and Discussions

I. Dry-matter determination

Dry weights of tops and roots of various treatments are summarized in Tables 1 and 2. That the dry weight of the root system was about 3 times that of the top in the control may be due to the compaction-free sand medium which is conducive to profuse root proliferation.

Table 1 : Dry-matter production of above-ground part

Treatment	*Dry matter of above-ground part (g/pot)	% of control
1. Control	9.53	100.00
2. Minus N	0.94	9.85
3. Minus P	1.16	12.17
4. Minus K	8.36	87.72
5. Minus all	0.70	7.35
6. Minus Mg	9.46	99.27
7. Minus Fe	9.23	96.85

*Average of 3 pots.

Table 2 : Dry-matter production of root system

Treatment	*Dry matter of root system	
	(g/pot)	% of control
1. Control	29.43	100.00
2. Minus N	4.87	16.55
3. Minus P	4.19	14.24
4. Minus K	9.51	32.31
5. Minus all	4.35	15.39
6. Minus Mg	7.88	26.78
7. Minus Fe	9.17	31.16

*Average of 3 pots.

II. Description of symptoms

Initially all cultures turned reddish purple on exposure to full sun, irrespective of treatment, and this is thought to be a reactionary effect to heat. Later, as new blades emerged, these affected blades aborted.

Deficiency symptoms of total omission of nutrients, nitrogen, phosphorus, magnesium and iron became evident within the first four weeks of culture and became more marked with increasing period of starvation with respect to the element under study. Deficiency symptoms of potassium surfaced only after about 10 weeks and then concurred with a drastic reduction in proliferation. Such observations tend to suggest that nitrogen, phosphorus, magnesium and iron nutrition of *Axonopus compressus* may take priority initially over that of potassium.

Treatment 1 : Minus Nitrogen

The symptoms resembled those of total omission of nutrients. They were first seen on the older blades. A reddish purple tint initially manifested itself along the entire margin of the blade and extended from tip to base in a streaky manner. A purplish colouration has been described for bermudagrass suffering from prolonged nitrogen deficiency. The initial symptom, however, was chlorosis (Oertli, 1963 cited by Beard 1973). Gradually, the reddish purple colouration imbued the entire blade, with the veins being more outstandingly coloured. Eventually the blade became necrotic and died. Both tillering and blade size were markedly reduced. Inflorescences were either not formed or withered away prematurely (Plate 1 : a, b and c). The root system appeared stunted compared with that of the control (Plate 4 : a). Dry-matter production was reduced. (Table 1 & 2).

Treatment 2 : Minus Phosphorus

Phosphorus deficiency manifested itself by the spreading of a dark purple discolouration from tip to base of the blade, commencing with the older blades. This symptom is typical of phosphorus deficiency. This one-step development of the purple discolouration resembles that observed for Merion Kentucky bluegrass. (*Poa pratensis*). However in some temperate grasses e.g. seaside creeping bentgrass (*Agrostis palustris*) and Pennlawn red fescue (*Festuca rubra*), the colour development begins from dark green, turns to dull blue-green and then to purple (Beard, 1973). On some blades, the veins remained green. When the development of the dark purple colouration became advanced or complete, necrosis



a



d



b



e



c



f

Plate 1. Deficiency symptoms : Top

Treatment 1 : a – c

- a = Top view : control (left), Nitrogen-deficient (right)
- b = Tiller : control (left), Nitrogen-deficient (right)
- c = Sequence of symptom development : control (left), Nitrogen-deficient (right)

Treatment 2 : d – f

- d = Top view : control (left), Phosphorus-deficient (right)
- e = Tiller : control (left), Phosphorus-deficient (right)
- f = Sequence of symptom development : control (left), Phosphorus-deficient (right)

began from tip to base and finally took its toll on the blade. Few new tillers were formed and blade size reduced. Inflorescences were either not formed or died prematurely (Plate 1 : d, e and f). The dry mass of the top and root was significantly reduced in comparison with that of the control (Plate 4 : b; Tables 1 & 2).

Treatment 3 : Minus Potassium

For the first 10 weeks of culture or thereabouts, no deficiency symptom was apparent. Growth was also unaffected. After 10 weeks of culture, symptoms began to emerge, accompanied by a distinct reduction in tillering and tiller size. The newly-formed blades were comparatively smaller than the old ones. Deficiency symptoms first appeared on the older blades as a partial interveinal chlorosis intermingled with a random display of dirty dark-brown speckles. Such interveinal chlorosis has been reported as a symptom of K deficiency in temperate grasses (Beard, 1973). In advanced deficiency, the tip of the blade became necrotic. This condition spread downwards and towards the base of the blade and literally killed it. Inflorescence production was checked at the later stage of deficiency (Plate 2 : a, b and c). The root system appeared smaller and had a lower dry weight than that of the control (Plate 4 : c; Table 2). Top dry-matter production was not very much reduced (Table 1) after 3 months as the recession in growth commenced only 10 weeks after treatment.

Treatment 4 : Total Omission of Nutrients

The overall symptom manifestation remarkably resembled that of the minus nitrogen treatment as described above, indicating that nitrogen nutrition is ranked foremost for *Axonopus compressus* (Plate 2 : d, e and f). The root system was very much inhibited in the absence of all nutrients (Plate 4 : d). Dry-matter production was greatly reduced (Tables 1 & 2). Although old tillers died back and new ones were sparse, they were very persistent after a period of 3 months in an environment which was supposedly nutrient-free, thus showing the remarkable hardiness of *Axonopus compressus*. In Treatments 1, 2 and 4, the top growth was so very much reduced that the pots had a bare look.

Treatment 5 : Minus Magnesium

The development of magnesium deficiency symptoms in *Axonopus compressus* is perhaps, the most prominent in terms of the display of colours. The older blades were affected first. Initially interveinal chlorosis prevailed, followed by the spreading of a cherry-red colouration from tip to base. A random distribution of yellow speckles developed against the cherry-red background. In the advanced stage, the individual blade became uniformly coloured to a bright cherry-red and necrosis commenced from tip to base, causing mortality of the blade. This symptom manifestation is somewhat similar to that of magnesium-deficient temperate grasses. However, the blades in the present trial did not turn completely yellow (cf Beard, 1979). There was no apparent reduction in top growth and inflorescence production (Plate 3 : a, b and c; Table 1). The root system appeared healthy but had a lower dry weight than that of the control (Plate 4 : e; Table 2).

Treatment 6 : Minus Iron

Iron deficiency in *Axonopus compressus* began as a striking yellowing of blades as in iron-deficient temperate grasses (Beard 1973). The newly-emerged blades developed interveinal chlorosis while the older blades remained quite green and healthy. In the later stage



a



d



b



e



c



f

Plate 2. Deficiency symptoms : Top

Treatment 3 : a – c

- a = Top view : control (left), Potassium-deficient (right)
- b = Tiller : control (left), Potassium-deficient (right)
- c = Sequence of symptom development : control (left), Potassium-deficient (right)

Treatment 4 : d – f

- d = Top view : control (left), minus all (right)
- e = Tiller : control (left), minus all (right)
- f = Sequence of symptom development : control (left), minus all (right)

of iron deficiency, the younger blades were almost completely depleted of chlorophyll and exhibited an acutely ivory discolouration which spread to the older blades. Tip and marginal necrosis both occurred randomly. Eventually the blade died. Inflorescence formation did not appear to be affected (Plate 3 : d, e and f). Whereas the top dry-matter accumulation was not adversely affected, the dry weight of the root system was reduced to about 31% that of the control (Plate 4 : f; Table 1 & 2). The iron contents in the control and treated grass were quite marginal (Table 3). This may be taken to imply that the difference in the levels for deficiency and sufficiency is small.

The remainder of the trial was monitored for a further period of 3 months. Nevertheless, no deficiency symptoms of trace elements were evident, meaning that either the sand was still contaminated with traces of these elements sufficient for the normal growth of the grass or that *Axonopus compressus* is not very sensitive to deficiency of these trace elements.

III. Results of elemental analysis

Table 3 : Results of elemental analysis of above-ground parts of *Axonopus compressus* on a dry weight basis

Treatment	Control grass	Treated grass	% of control
1. -N	1.47% N	0.91% N	61.90
2. -P	0.22% P	0.08% P	36.36
3. -K	1.48% K	0.25% K	16.89
4. -Mg	2515.0 ppm Mg	538.0 ppm Mg	21.39
5. -Fe	137.5 ppm Fe	119.9 ppm Fe	87.20
		(0.83% N	56.46
		(0.17% P	77.27*
6. -all		(0.83% K	56.08*
		(579.0 ppm Mg	23.02
		(249.1 ppm Fe	181.16*

Deficiency symptoms were further confirmed by tissue analysis of the above-ground parts of the control and treated grass. The results are tabulated (Table 3). These data denote deficient levels but do not necessarily represent the critical levels at which deficiency symptoms just begin to appear.

Conclusion

The deficiency symptoms of N, P, K, Mg and Fe were induced in *Axonopus compressus* and further confirmed by elemental analysis of above-ground part. Whereas the deficiencies in the semi-macro elements Mg and Fe only resulted in a multitude of dis-

*In the treatment with deionized water only, the efficiency of *Axonopus compressus* to accumulate P, K and especially Fe from contaminating sources appeared to have increased.



a



d



b



e



c



f

Plate 3. Deficiency symptoms : Top

Treatment 5 : a – c

- a = Top view : control (left), Magnesium-deficient (right)
- b = Tiller : control (left), Magnesium-deficient (right)
- c = Sequence of symptom development : control (left), Magnesium-deficient (right)

Treatment 6 : d – f

- d = Top view : control (left), Iron-deficient (right)
- e = Tiller : control (left), Iron-deficient (right)
- f = Sequence of symptom development : control (left), Iron-deficient (right)

colouration of blades and some reductions in dry-matter production, particularly of the root system, the deficiencies in the macro elements N and P, however, led to marked reductions in both tiller and root growth, inflorescence production, and to various discolourations of blades in *Axonopus compressus*. The deficiency symptom of K became evident only 10 weeks after treatment. From the intensity of symptom manifestation after 3 months, it is reasonable to speculate further reduction in growth if the trial were continued.

The experimental iron deficiency symptoms resembled the symptom developed by *Axonopus compressus* thriving on over-limed areas where the pH is 7.0 and above. A liming trial will be conducted to confirm the present observations. The present finding cautions the free-handed use of lime for *Axonopus compressus* substrates. Liming is best guided by soil analysis.

Acknowledgement

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References

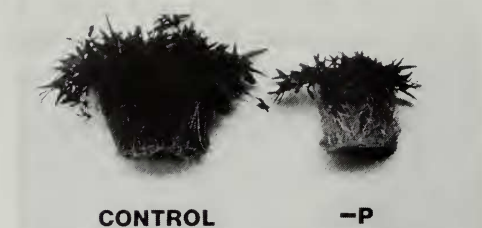
- Anonymous. 1977. *A handbook on the maintenance of school fields*. An information booklet published by the Parks & Recreation Department, Singapore.
- Asher, C.J. 1973. *Lecture and practical notes for short courses in applied plant nutrition*. Nanyang University, Singapore.
- Beard, J.B. 1973. *Turfgrass : Science and culture*. Prentice-Hall, Englewood Cliffs, and references therein.
- Beard, J.B. 1979. *How to have a beautiful lawn – Easy steps in turfgrass establishment and care for aesthetic and recreational purposes*. 2nd edition. Beard Books, Ohio.
- Chai, B.F. 1978. A study of the mineral deficiency and nitrate assimilation in Choy Sam (*Brassica chinensis*). Master's Thesis, Department of Biology, Nanyang University, Singapore.
- Gilliland, H.B. 1953. *A revised Flora of Malaya*. Volume III. *Grasses of Malaya*, p. 187. The Government Printing Office, Singapore.
- Madison, J.H. 1971. *Principles of turfgrass culture*. Van Nostrand Reinhold, New York.
- Oertli, J.J. 1973. Nutrient disorders in turfgrass. *California Turfgrass Culture*, Vol 3, No. 3, 17-19. (cited by Beard, 1973).
- Vengris, J. 1973. *Lawns : Basic factors, construction and maintenance of fine turf areas*. 2nd edition. Thomson, Indianapolis.



a



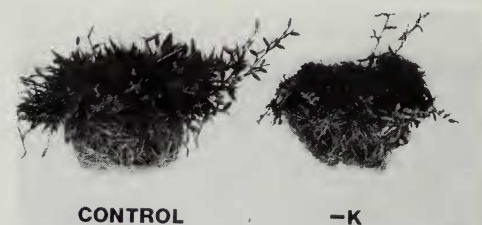
d



b



e



c



f

Plate 4. Deficiency symptoms : Root system

- a (Treatment 1) = control (left), Nitrogen-deficient (right)
- b (Treatment 2) = control (left), Phosphorus-deficient (right)
- c (Treatment 3) = control (left), Potassium-deficient (right)
- d (Treatment 4) = control (left), minus all (right)
- e (Treatment 5) = control (left), Magnesium-deficient (right)
- f (Treatment 6) = control (left), Iron-deficient (right)

APPENDIX 1 : Formulations for Stock Solutions and Nutrient Solutions

Stock solution	Control (ml)	-N (ml)	-P (ml)	-K (ml)	-Ca (ml)	-Mg (ml)	-Fe (ml)	-S (ml)	Weight of salt (g)	Volume (ml)
1M Ca(NO ₃) ₂ .4H ₂ O	10	—	10	10	—	10	10	10	472.00	2,000
1M KNO ₃	10	—	10	—	10	10	10	10	202.00	2,000
0.2M KH ₂ PO ₄	10	10	—	—	10	10	10	10	54.40	2,000
1M MgSO ₄ .7H ₂ O	4	4	4	4	4	—	4	—	247.00	1,000
1M NaNO ₃	—	—	—	10	20	—	—	—	128.00	1,500
1M CaCl ₂	—	10	—	—	—	—	—	—	56.00	500
1M KCl	—	10	1	—	—	—	—	—	39.30	500
1M MgCl ₂ .6H ₂ O	—	—	—	—	—	—	—	4	40.70	200
1M Na ₂ SO ₄	—	—	—	—	—	4	—	—	28.40	200
1M NaH ₂ PO ₄ .2H ₂ O	—	—	—	1	—	—	—	—	31.20	200
(CH ₂ N(CH ₂ .COO) ₂) ₂ FeNa	2	2	2	2	2	2	—	2	41.70	500
H ₃ BO ₃	2	2	2	2	2	2	2	2	1.43	500
MnSO ₄ .H ₂ O	2	2	2	2	2	2	2	2	2.00	500
ZnSO ₄ .7H ₂ O	2	2	2	2	2	2	2	2	1.15	500
CuCl ₂ .2H ₂ O	2	2	2	2	2	2	2	2	0.26	500
(NH ₄) ₆ Mo ₇ O ₂₄ .4H ₂ O	2	2	2	2	2	2	2	2	0.02	500

Notes

1. All chemicals used were analar grade.
2. For the individual trace elements, the formulation for the control excluding the trace element in question was used.
3. All the above formulations were made up to 3 litres before application.

Appendix 2 : Concentration of individual mineral elements in nutrient solutions

Nutrient solution														
	N	P	K	Ca	Mg	Fe	S	B	Mn	Zn	Cu	Mo	Na	Cl
Control (complete)	139.9	20.6	156.3	133.3	32.5	8.5	43.50	0.33	0.87	0.43	0.15	0.015	3.5	0.11
−N	0	20.6	163.1	134.5	32.5	8.5	43.50	0.33	0.87	0.43	0.15	0.015	3.5	239.11
−P	139.9	0	143.9	133.3	32.5	8.5	43.50	0.33	0.87	0.43	0.15	0.015	3.5	12.61
−K	140.1	10.3	0	133.3	32.5	8.5	43.50	0.33	0.87	0.43	0.15	0.015	88.2	0.11
−Ca	140.2	20.6	156.3	0	32.5	8.5	43.50	0.33	0.87	0.43	0.15	0.015	157.5	0.11
−Mg	139.9	20.6	156.3	133.3	0	8.5	42.70	0.33	0.87	0.43	0.15	0.015	64.8	0.11
−Fe	139.9	20.6	156.3	133.3	32.5	0	43.50	0.33	0.87	0.43	0.15	0.015	0	0.11
−S	139.9	20.6	156.3	133.3	32.4	8.5	0.67	0.33	0.87	0.43	0.15	0.015	3.5	94.91
−B	139.9	20.6	156.3	133.3	32.5	8.5	43.50	0	0.87	0.43	0.15	0.015	3.5	0.11
−Mn	139.9	20.6	156.3	133.3	32.5	8.5	42.96	0.33	0	0.43	0.15	0.015	3.5	0.11
−Zn	139.9	20.6	156.3	133.3	32.5	8.5	43.50	0.33	0.87	0	0.15	0.015	3.5	0.11
−Cu	139.9	20.6	156.3	133.3	32.5	8.5	43.50	0.33	0.87	0.43	0	0.015	3.5	0
−Mo	139.9	20.6	156.3	133.3	32.5	8.5	43.50	0.33	0.87	0.43	0.15	0	3.5	0.11